VIII. PHOSPHORUS BUDGET

A. Development of Phosphorus Budgets

The calculation of a phosphorus budget is an essential step in the evaluation of a lake's trophic status. A phosphorus budget provides a means to evaluate and rank phosphorus sources that may contribute to algal problems. It is most important to realize the quantity of nutrients (especially phosphorus) entering the lake, as well as the ultimate fate of those nutrients. The phosphorus budget relies heavily upon the accuracy of the hydrologic budget for its input and output variables, and is important when modeling the lake's tolerance to inflowing phosphorus.

Many extensive nutrient budgets have been reported in the literature. Lake Washington in Seattle, Washington (Edmondson, 1968), Lake Erie (Burns, 1976), and Kezar Lake, North Sutton, New Hampshire (Connor and Smith, 1983) have been studied in great detail.

Nutrient loading rates have been reported as either "surface loading rates" or "volumetric loading rates" and are usually expressed in terms of mass per unit area-time, and mass per unit volume-time.

The purpose of this chapter is to quantify the various avenues of phosphorus inputs into Mendums Pond and to explore the various phosphorus sinks and exports from the watershed. Phosphorus loadings (flux) were calculated for each tributary inflow, outflow, direct runoff, atmospheric, groundwater, and septic leachate to Mendums Pond. A phosphorus budget was then prepared for the 1987-88 study year.

B. Phosphorus Budget Components

1. Tributary loading and discharge

Tributary phosphorus concentrations were analyzed and monthly loadings were calculated for each of the Mendums Pond stations. Phosphorus loadings were determined by calculating mean monthly tributary flows ($10^3 m^3$) and multiplying these values by mean monthly phosphorus concentrations (mg/L). The resultant values represent mean monthly phosphorus loading or flux (Kg P). The summations of each of the calculated monthly values equals the total tributary annual phosphorus loading.

Table VIII-1 shows the monthly tributary phosphorus load to Mendums Pond. Perkins Brook contributed 95 Kg of phosphorus to Mendums Pond during the 1987-88 study year or 54 percent of the tributary phosphorus load. McDaniel Brook provided 48 Kg of phosphorus or 27 percent of the total tributary loading. The third greatest phosphorus producer was Bridge Brook which donated 13 Kg and 7.5 percent. Each of the other tributaries combined, contributed less than 12 percent of the tributary budget.

2. Atmospheric

Atmospheric inputs consist of two major components: (1) wind transported material, commonly referred to as dryfall, removed from the air by sedimentation or impaction; and (2) soluble gases or salts that are scavenged by rainfall. Estimates for the dryfall portion alone may be as high as 70-90 percent of the total atmospheric load (Likens and Loucks, 1978).

In agrarian areas, increases in nutrient loads transported via the atmosphere can be attributed to agricultural activities and associated soil disturbances. Urban atmospheric inputs of nutrients can be attributed primarily to combustion emissions.

Atmospheric phosphorus loading (wetfall and dryfall) for Mendums Pond was determined by the direct measurement of phosphorus in rain samples collected in Concord, New Hampshire and from rainfall. While dryfall was calculated utilizing dryfall export coefficients (Reckhow, et al, 1980). The measured mean phosphorus concentration calculated for the sample season was than multiplied by the monthly rainfall and the lakes surface area to obtain P lake. The atmospheric phosphorus contribution to Mendums Pond during the study period was 44 Kg with a mean monthly load of 3.7 Kg. Since the phosphorus load from atmospheric deposition is dependent on annual weather patterns, the greatest phosphorus contributions occur during the wettest seasons. This will be discussed in greater detail in the phosphorus budget sections. The mean monthly contribution of atmospheric phosphorus during the study period was 3.7 Kg-P. The months of July and August contributed 42 percent of the total annual atmospheric phosphorus loading to Mendums Pond.

Table VIII-1
Monthly Tributary Phosphorus Load to Mendums Pond (Kg)

	87 Nov	87 Dec	88 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Mean Monthly	Total Annual
Perkins	2.9	8.9	4.6	12.3	8.3	7.0	8.6	2.4	5.6	19.7	3.7	11.3	8.0	95.4
McDaniels	1.3	2.8	1.5	2.1	1.8	2.3	2.3	1.7	7.7	18.5	2.5	4.0	4.0	48.4
Bridge	0.2	0.7	0.1	0.2	0.2	0.4	2.7	0.2	4.7	1.6	1.4	1.0	1.1	13.4
Little Bridge	0.6	0.1	0.0	0.0	0.1	0.2	0.3	0.0	1.6	2.8	0.0	0.9	0.6	6.6
Wood Road	0.1	0.8	0.2	0.2	0.2	0.2	0.5	0.1	0.6	1.5	0.2	0.1	0.4	4.7
Howe	0.9	0.3	0.1	0.2	0.2	0.1	0.1	0.1	0.3	0.4	0.5	0.1	0.3	3.4
Golden	0.2	0.2	0.1	0.1	0.6	0.1	0.1	0.0	0.5	0.5	0.03	0.3	0.2	2.9
Powerline	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	1.8
Howe II	0.09	0.05	0.09	0.06	0.04	0.03	0.0	0.1	0.1	0.0	0.0	0.1	0.05	0.6
Storm Brook	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.0	0.3	0.0	0.0	0.03	0.4
Little Powerline	0.04	0.02	0.03	0.01	0.02	0.02	0.03	0.01	0.02	0.07	0.00	0.02	0.02	0.3
Seasonal Brook	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.03	0.03	0.00	0.02	0.02	0.2

3. Direct Surface Runoff

Direct surface runoff includes the water and its transported phosphorus that does not enter a lake via tributary or groundwater. Direct surface runoff is the result of near shore snowmelt and rainfall, especially during high intensity storms.

Loadings in runoff from shoreline areas can be estimated indirectly. In many cases, indirect estimates of loading from an area can be derived from information on watershed characteristics. This method is based on the concept that two watersheds in the same region and with similar land use patterns and geology will tend to contribute the same loading of phosphorus per unit area. This permits extrapolation of data from one or more monitored watersheds to others.

Shoreline runoff areas at Mendums Pond were designated as mixed forest and urban, low density residential. Table VIII-2 shows the selected export coefficient and total phosphorus export for each watershed designation. To obtain the direct phosphorus runoff contribution to Mendums Pond, the designated land use areas that did not drain into a monitored tributary were determined. A phosphorus coefficient for each land use was selected by matching a land use characterization of known phosphorus load to that land use which closely reflected the land use at Mendums Pond. The direct phosphorus runoff was calculated by multiplying the land use area by the phosphorus coefficient.

Increased phosphorus load to a lake from direct runoff corresponds to the area's weather patterns. During periods of frozen ground and snowmelt, and high intensity rainstorms usually contribute an increased phosphorus load via runoff.

Direct runoff contributed 44 Kg of phosphorus to Mendums Pond during the study period. The mean monthly phosphorus contribution to Mendums Pond was 4.2 Kg during the study year.

Table VIII-2

Mendums Pond Watershed Phosphorus Export

Watershed Designation	Percent	Area (ha.)	Export Coefficient (Kg/ha/yr)	Phosphorus Export (Kg)
Forested/Mixed	56	48	0.20	9.6
Urban/Low Dens. Residential	44	38	0.90	39.6

4. Septic Leachate

Septic tanks and leachfields are another non-point source that must be considered as a nutrient source because of their potential for nutrient enrichment of the groundwater which flows into a lake.

Several studies (e.g., Jones and Lee, 1977; NHWS&PCC, 1975) have indicated that a properly designed, constructed, and maintained system will not generally contribute significant amounts of phosphorus to surface waters. However, because of their use in unsuitable areas or because of improper design, construction, or maintenance, it is estimated that over one-half of the systems in use today fail before their designed life of fifteen to twenty years is completed (Scalf _et al_., 1977).

The most common type of individual disposal system is the septic tank-leach field system. The tank functions to separate the solids, both floating and settleable, from the liquid material. The accumulated sludge should be pumped out every three to five years. The liquid is discharged from the tank through piping material and distributed over the leaching area, which is designed to absorb the effluent and to remove the impurities before it percolates to the groundwater.

In 1967, the New Hampshire legislature enacted a law to protect water supplies from pollution by subsurface disposal systems, and directed the Water Supply and Pollution Control Division to establish minimum, state-wide requirements for properly designed systems. The information required to estimate the phosphorus loading from septic systems is:

1. Location of the system with respect to the surface water body,
2. Soil permeability: the rate of water transmission through saturated soil, of which estimated soil retention coefficients varied with different lake sections,
3. Land slope: steep slopes may cause erosion problems when associated with soils of low permeability,
4. System age: soils have only a finite capacity for phosphorus absorption,
5. Per capita occupancy: (household population based on sanitary survey),
6. Fraction of year system is in use: (i.e., summer cottages or year-round dwellings), and
7. Additional water utilizing machinery: (i.e., washing machines, dish washers, or garbage disposals).

In most Diagnostic/Feasibility Studies, a survey of individual sanitary waste-disposal systems around the lake is conducted by the Water Supply and Pollution Control Division. The survey consists of a visual inspection of the property, interviews with residents to discuss various problems, and the compilation of certain statistical information regarding the system, such as type of system, age, maintenance schedule, depth to groundwater etc. A copy of the form used during the survey is included in Appendix VIII-1.

The soils around the lake ranged from having slight to severe limitations for subsurface disposal. Much of the lakefront property, however, appeared to be on fill areas.

The State of New Hampshire requires that there be a vertical distance of four feet between the bottom of the leachfield and the seasonal high water table. Additionally, a lateral separation of 75 feet between the leachfield and any surface water is required. Generally, it appears that while the present systems do not necessarily constitute health hazards, they are contributing a phosphorus load to the lake. A special monitoring study conducted at a Mendum's Pond septic system showed that the surrounding soils have a limited capacity to uptake phosphorus and that the short distance between the soil layer and bedrock accelerated the leachfield flow to the lake. The results of this monitoring program are discussed in the groundwater section of this chapter.

The amount of phosphorus contributed to Mendums Pond in a given year by subsurface disposal systems was determined by the following equation:

$$\text{Kg P year}^{-1} = (\text{Kg P Capita}^{-1}\ \text{year}^{-1})\ (\#\ \text{homes})$$

$$(\#\ \text{Capita house}^{-1})\ (\#\ \text{years})\ (1\text{-soil retention coefficient})$$

Permanent home phosphorus loading was calculated by utilizing 15 living units as year-round homes. It was estimated that on the average, 2.5 persons occupy year round homes. Since the soils are considered severe and because of the short depth of soil to bedrock, a 0.2 was assigned as the Soil Retention Coefficient. Permanent homes contributed 30 Kg phosphorus for the study year.

Seasonal home phosphorus loading was determined utilizing 60 as the number of seasonal cottages. It was estimated that 3.5 persons occupy seasonal cottages for a 100 day period. Seasonal homes contributed 36.8 Kg phosphorus over a 100 day period. It was assumed that the permanent homes had washing machines and the seasonal homes did not and therefore the permanent homes contributed more phosphorus per capita. The total phosphorus load to Mendums Pond from septic systems was estimated to be 66.8 Kg P/year.

5. Groundwater

Relatively little is known of groundwater seepage nutrient concentrations and their importance to nutrient budgets. Lee (1977) first applied the direct seepage meter technique in Lake Sallie, Minnesota, in an attempt to monitor the contribution of nutrients from septic tanks located around the lake. He concluded that all septic tank phosphorus appeared to be bound to the soil, but that 40 percent of the nitrogen from the septic tanks entered the lake. In the past, well-water along the lake's boundary was analyzed for an estimate of nutrient input via seepage. The utilization of this type of methodology, however, does not account for nutrient concentration differences within the water table profile and does not include sediment interactions with seepage water (Connor, 1979).

A great deal of emphasis was placed on groundwater sampling and analyses for the Mendums Pond project. However, only the interstitial pore water was utilized in calculating the groundwater phosphorus component of the nutrient budget. A list of each of the groundwater monitoring programs conducted at Mendums Pond and a summary of the analyses is provided below.

a. Groundwater Seepage

A series of 16 seepage meters were placed throughout the shoreline area of Mendums Pond. One small transect into deeper surface waters was placed in Mendums to determine the effect of water depth and seepage rates. Also, two meters were placed a short distance from each other as quality control meters to estimate accuracy of seepage meters. No chemical analyses were performed on seepage meter water because interstitial pore water samples were being analyzed. A discussion on seepage meters and Mendums Pond groundwater seepage rates is included in the hydrologic budget chapter.

b. Shallow Dug Well Analyses

A series of shallow dug wells were sampled at different locations along the Mendums Pond shoreline. The samples were analyzed for phosphorus concentration. The shallow well phosphorus concentration results were compared to other groundwater sample sources. Well depth ranged from a minimum of 12 feet to a maximum depth of 25 feet.

Phosphorus concentration was significantly lower in the shallow wells than phosphorus concentrations measured in the interstitial water and in the septic system monitoring wells. The phosphorus concentration ranged from a minimum of 3 ug/L in the 25ft. well to a maximum of 10ug/L in the 12 ft. shallow well. The mean phosphorus concentration for the shallow wells was 6.4ug/L.

c. Interstitial Pore Water

A specially designed interstitial pore water sampler (IPWS) (Figure VIII-1) was utilized in this study to collect interstitial water. The IPWS was placed in the sediment while interstitial water was pumped through a fine screen and into a sample bottle. Figure VIII-2 shows the location of each station on Mendums Pond that interstitial water was sampled.

Table VIII-3 is a summary of the chemical analyses performed on the interstitial water. Appendix VIII-2 lists all the results collected throughout the three year study period.

Each of the interstitial pore water samples were acidic with a minimum pH of 4.0 and a maximum pH of 6.8. The lowest mean pH value of 5.8 was measured at station 4 while the highest mean pH value was measured at station 2.

The conductivity of interstitital pore water was generally higher than that measured in the surface water. The range of conductivity measured throughout the sampling sites ranged from a minimum of 23 umhos/cm at station 3, to a maximum conductivity of 225 umhos/cm measured at site 4. Mean conductivity measurements of each station revealed a similar trend with station 3 having the lowest mean conductivity of 26 umhos/cm and station 4 having the highest mean conductivity of 124 umhos/cm.

Interstitial pore water phosphorus concentrations were significantly higher than shallow well water phosphorus and hypolimnetic surface water phosphorus, but were lower than phosphorus levels measured in the groundwater monitoring wells placed downslope of a septic system. Interstitial water

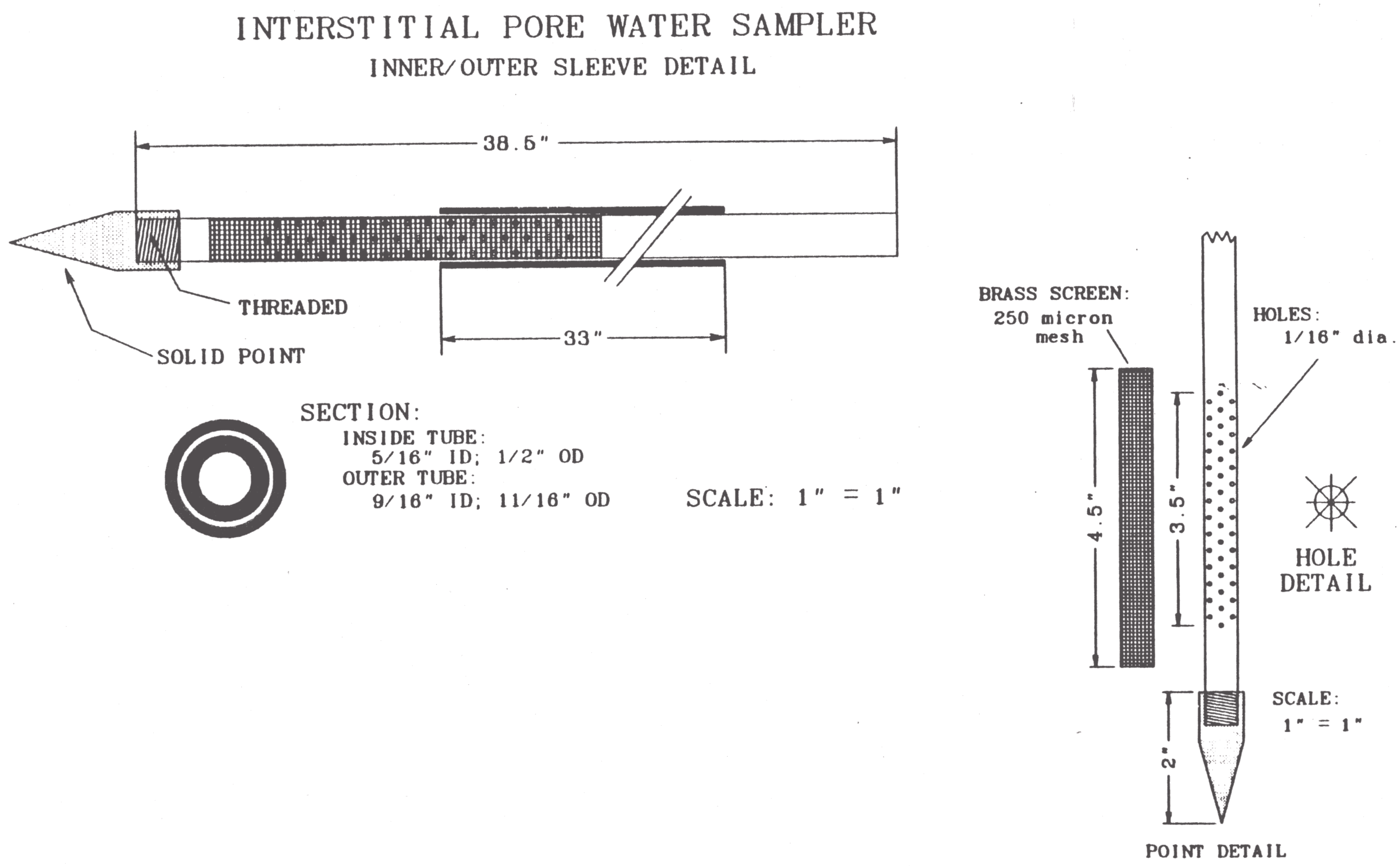


Figure VIII-1 IPWS sampler

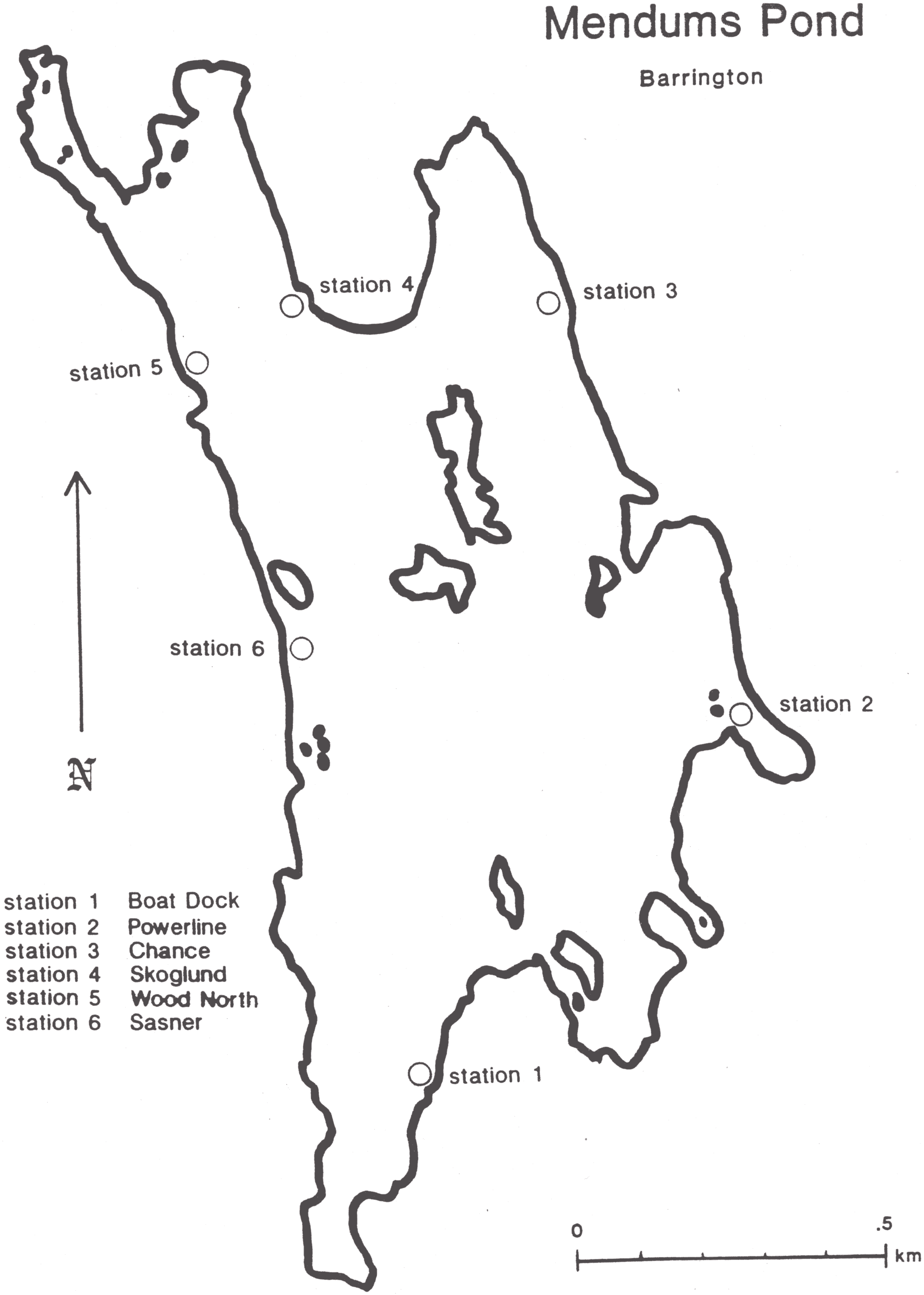


Figure VIII-2 Interstitial Porewater Sample Locations

Table VIII-3

Mendums Pond Interstitial Pore Water Analyses

Station	pH (units)		Conductivity (umhos)		Phosphorus (ug/L)	
	range	mean	range	mean	range	mean
1	5.8-6.4	6.2	28.1-33.2	30.8	5-47	20.5
2	5.9-6.8	6.4	34.4-42.3	36.4	11-68	35.5
3	5.7-6.6	6.3	23.0-35.4	26.1	7-160	68.5
4	4.0-6.0	5.8	51.3-22.5	123.8	5-137	51.4
5	5.5-6.3	6.0	54.3-78.4	61.8	14-339	137.1
6	5.3-6.3	6.1	43.9-60.4	47.1	12-133	54.5

phosphorus ranged from a minimum concentration of 5 ug/L at sites 1 and 4 to a maximum concentration of 339 ug/L at site 5. The lowest mean phosphorus concentration was measured at station 1 while the highest mean phosphorus concentration was measured at station 5.

The seepage phosphorus contribution to Mendums Pond was derived from calculating the mean of the mean interstitial phosphorus concentrations (excluding the high value measured at station 5) obtained during the study period throughout the pond. The seepage rate calculated for the hydrologic budget and the measured mean phosphorus concentrations from the interstitial water reflect the total loading of groundwater seepage to the pond. Seepage loading varied with the monthly seepage rates to Mendums Pond.

d. Groundwater Monitoring Wells

Leachfield monitoring wells were installed at one of the homes at the new development on May 19, 1988. The monitoring wells were situated in Charlton type soils. These soils are well-drained, have moderate permeability and moderate available water capacity. The depth to bedrock is relatively shallow, ranging from 4'10" to 6'7". The slope of the area between the leachfield and the pond was eight to ten percent.

The wells were sampled weekly for total phosphorus, and less frequently for other parameters important in identifying septic leachate. Five wells were installed - two at about 20 feet from the leachfield, approximately 15 feet apart from each other; the next well was about 60 feet from the leachfield, but contained no water throughout the study; the next two were about 90 feet and 140 feet from the leachfield (Figure VIII-3). This would allow us to determine if pollutants were traveling through the soil and into the pond.

Samples analyzed from each of the leachfield monitoring wells showed very high concentrations of phosphorus. Table VIII-4 shows certain water quality parameters compared between the monitoring wells, residence dug wells and interstitial pore water. Median phosphorus values were significantly higher in the leachfield wells while the interstitial water was higher than the dug wells around the pond. Interstitial water is usually much higher than surrounding well water because it has interaction with the organically phosphorus rich lake sediments. Leachfield total nitrogen concentrations were very high. Median leachfield conductivity ranged from 27 to 55 umhos/cm while median IPW ranged from 25 to 106 umhos.

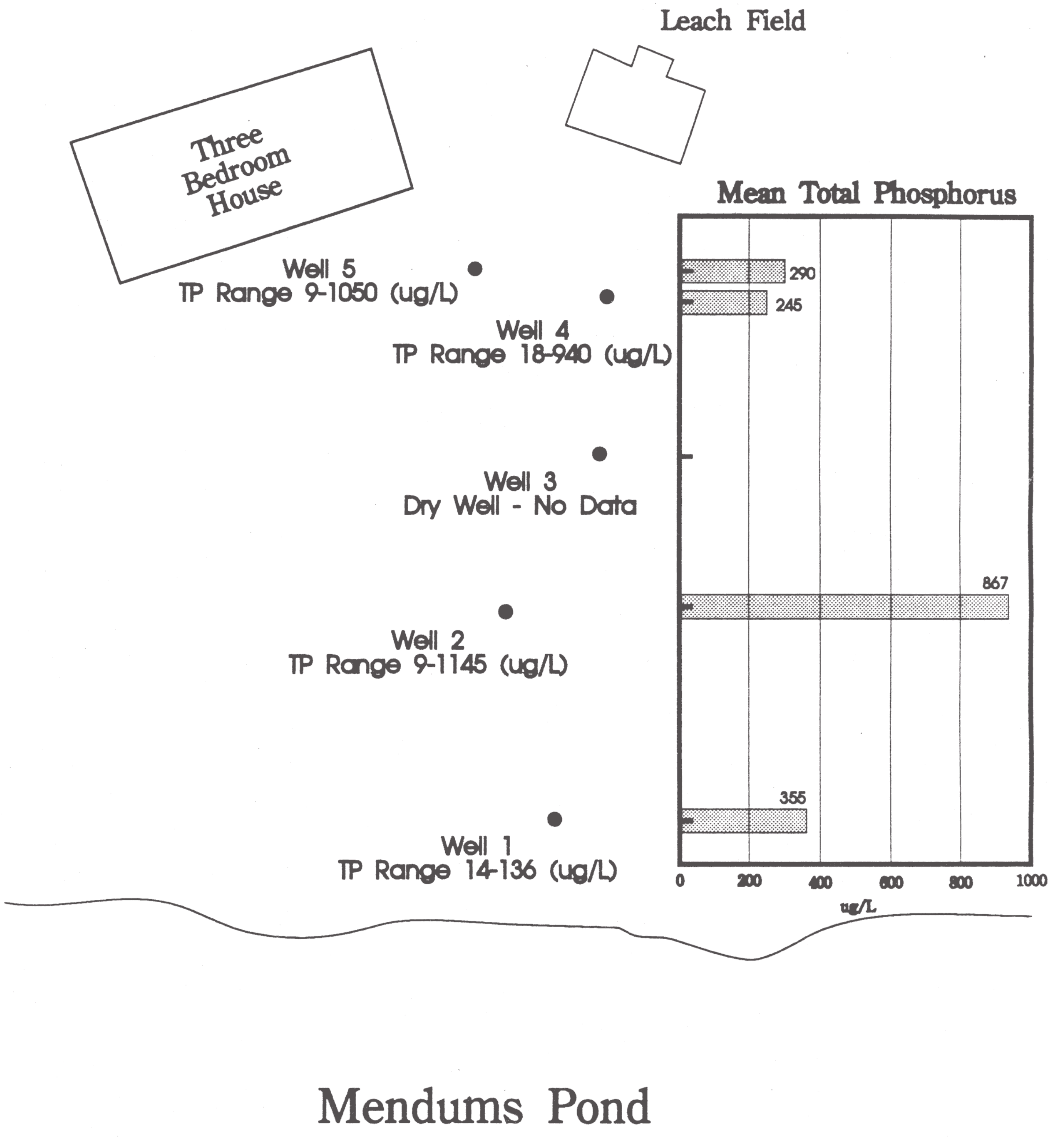


Figure VIII-3. Mendums Wells, Location and Mean Phosphorus Values.

Table VIII-4

Mendums Pond

Groundwater Monitoring Study

Median Values 1988 - 1990

	pH	Conductivity	Cl	Tp	TKN	NO_3	SO_4
I Leachfield Wells							
#1	5.39	32.78	241	375	.05	6	2.9
2	5.29	26.52	530	---	.05	5.8	4.9
4	5.23	51.50	192	700	.05	25.11	23.0
5	5.46	54.81	241	9860	8.56	27.96	16.7
II Dug Wells	---	---	26	---	---	---	---
III Interstitial Wells							
Sasner	5.90	52.90	45	---	---	---	---
Boat Dock	6.04	30.32	23	---	---	---	---
Powerline	6.37	35.90	38	---	---	---	---
Chance	6.36	25.00	74	---	---	---	---
Skoglund	5.66	106.00	64	---	---	---	---
Wood North	5.90	58.90	194	---	---	---	---

Mean phosphorus concentrations in the monitoring wells closest to the leachfield were similar but these wells were lower than wells one and two closest to the lake (Figure VIII-3). Nitrogen, conductivity and chloride all decreased as the distance from the leachfield increased (Table VIII-5).

On December 20, 1988 a fluorescein dye was added to the septic system via the toilet. The wells were sampled each day for a week, to be analyzed using a fluorometer. Two days after the dye was added, it appeared in all of the four wells, but was most apparent in the two wells nearest the leachfield. Ten days later, the wells were back to the original values observed in the fluorometer prior to dyeing.

On October 9, 1989 the dye study was again initiated. Accidently, a very large amount of dye was added. The next day the two wells nearest the leachfield were showing very high fluoresence - observable with the naked eye, as well as in the fluorometer. For a month the wells were sampled, showing high fluoresence the entire time in the two wells nearest the leachfield. The well closest to the pond showed low fluoresence. One year later, the red dye was still visible in the two wells nearest the leachfield.

The results of this special study suggests that under these soil conditions, even a new state-of-the-art septic system can allow nutrients to make their way through the soil, to the bedrock and finally into the lake.

e. Groundwater Summary

Several groundwater sources were sampled throughout the Mendums Pond study. These groundwater sources included well water from drinking water sources around the lake, interstitial water from the sediments of Mendums Pond, and special inspection wells placed downslope of a new septic leachfield at Mendums Landing. Only the interstitial phosphorus analyses were utilized to calculate the phosphorus loading component of the budget.

The results showed that the dug wells surrounding the pond had low phosphorus concentrations.

Because of the groundwater interaction with the organically phosphorus rich sediments and the potential of accumulating septic leachate water, the interstitial water contained moderate to high amounts of phosphorus.

The septic leachate special study revealed the highest groundwater phosphorus concentration. This study concluded that even a new state-of-the-art septic system can allow nutrients to readily make their way through the soil, to the bedrock and finally into the lake.

TABLE VIII-5

Mendums Pond

Leachfield Monitoring Well Data

Well #1

Parameter	Minimum	Maximum	Mean
pH	5.2	5.5	5.4
Conductivity	28.2	98.6	66.9
Phosphorus	14	136	355
Fecal Coliform	0	0	0
TKN	0.1	0.5	0.3
Nitrate	0.05	0.18	0.07
Sulfate	2.6	20.0	12.4
Chloride	---	12.0	5.0

Well #2

Parameter	Minimum	Maximum	Mean
pH	5.2	5.4	5.3
Conductivity	26.1	119.0	68.7
Phosphorus	9	1145	867
Fecal Coliform	0	0	0
TKN	0.1	0.3	0.2
Nitrate	0.13	0.05	0.26
Sulfate	11.9	22.0	11.9
Chloride	4.0	---	14.0

Well #4

Parameter	Minimum	Maximum	Mean
pH	5.0	5.5	5.2
Conductivity	43.9	534.5	278.6
Phosphorus	18	940	245
Fecal Coliform	0	4	--
TKN	0.7	9.2	4.3
Nitrate	0.05	27.7	13.9
Sulfate	4.6	58.0	28.5
Chloride	---	53.0	19.7

Well #5

Parameter	Minimum	Maximum	Mean
pH	5.3	5.8	5.5
Condutivity	44.3	703	328.4
Phosphorus	9	1050	290
Fecal Coliform	0	0	0
TKN	0.6	10.7	8.0
Nitrate	0.05	36.8	20.1
Sulfate	4.1	56.0	31.0
Chloride	---	46.0	20.3

6. Sediment Release-Uptake

The fate of phosphorus in water is usually considered to consist of chemical, physical, or biological transformation of the ionic form into a particle, sedimentation of this particle to the bottom, particle breakdown in the sediment, and the release of some of the ionic phosphorus back into the lake water if conditions are favorable.

The actual measurement of total phosphorus release or uptake from the sediment is an impractical task to attempt. Since sediment release and uptake are occurring simultaneously in different sections of a lake, and other chemical, physical and biological activities are also occurring, it is virtually impossible to establish a realistic total phosphorus release or uptake figure. However, an estimation of net differences between total uptake and total release can be derived by calculating an internal phosphorus loading model. A positive mass balance solution represents net phosphorus release (loading) and a negative solution represents net uptake.

a. Internal Phosphorus Cycling

An essential component of the nutrient budget is the monthly net release or uptake of phosphorus from or to the lake sediments. In order to quantify this component, a phosphorus mass-balance equation was solved for each month of the sample period. Thus, by knowing the masses of phosphorus entering the lake and flowing out of the lake and the change of mass in the lake, the equation can be solved for the mass released or adsorbed by the sediments.

Mass is calculated as the product of concentration and volume. Table VIII-6 shows how the phosphorus mass in Mendums Pond, at the beginning of each month, was calculated as the sum of masses in each stratum. The volume of each stratum was calculated from areal measurements of contours on the bathymetric map.

Table VIII-7 reflects monthly values of each variable of the mass-balance equation and the resulting net uptake or release for Mendums Pond.

The mass-balance equation is:

$$P_{int} = (P_2 - P_1) - (P_{in} - P_{out})$$

where:

P_{int} = net phosphorus release (+) or uptake (-) by the sediments

TABLE VIII-6
In-Lake Phosphorus Mass For Mendums Pond

Date	Epilimnion P(mg/L)	Epilimnion M(Kg)	Metalimnion P(mg/L)	Metalimnion M(Kg)	Hypolimnion P(mg/L)	Hypolimnion M(Kg)	Total P Mass (Kg)
Nov-01-87	0.011	29.4	0.012	20.6	0.009	19.6	69.6
Dec-01-87	0.009	24.0	0.010	17.2	0.012	26.1	67.3
Jan-01-88	0.010	26.7	0.006	10.3	0.010	21.8	58.8
Feb-01-88	0.006	14.7	0.006	9.4	0.004	8.7	32.8
Mar-01-88	0.006	14.7	0.006	9.4	0.004	8.7	32.8
Apr-01-88	0.005	13.4	0.005	8.6	0.005	10.9	32.9
May-01-88	0.007	18.7	0.004	6.9	0.006	13.1	38.7
Jun-01-88	0.005	12.0	0.004	6.9	0.004	8.7	27.6
Jul-01-88	0.001	2.7	0.021	36.1	0.003	6.5	45.3
Aug-01-88	0.007	18.7	0.009	15.5	0.012	26.1	60.3
Sep-01-88	0.008	20.0	0.010	17.2	0.010	21.8	59.0
Oct-01-88	0.010	26.7	0.004	6.9	0.009	18.5	52.1
Nov-01-88	0.013	34.7	0.012	20.6	0.011	24.0	79.3

TABLE VIII-7
Monthly Internal Phosphorus Cycling
Mendums Pond 1987-1988 Gaging Year

Month	P_{in} Subtotal Inflow	P_{out} Total Outflow	Plake 1 (Kg)	Plake 2 (Kg)	P_{int} (Kg)
Nov	14.3	9.7	69.6	67.3	-6.9
Dec	21.6	8.2	67.3	58.8	-21.9
Jan	10.8	6.0	58.8	32.8	-30.8
Feb	20.8	3.3	32.8	32.8	-17.5
Mar	22.5	0.02	32.8	32.9	-22.4
Apr	27.8	3.2	32.9	38.7	-18.8
May	30.9	10.6	38.7	27.6	-31.4
Jun	22.4	0.2	27.6	45.3	-4.5
Jul	56.3	2.6	45.3	60.3	-38.7
Aug	80.8	10.5	60.3	59.0	-71.6
Sep	19.5	4.1	59.0	52.1	-22.3
Oct	28.8	5.9	52.1	79.3	+4.3

P_1 = in-lake phosphorus mass, beginning of month

P_2 = in-lake phosphorus mass, end of month

P_{in} = phosphorus mass flowing in during the month

P_{out} = phosphorus mass flowing out during the month

Figure VIII-4 demonstrates the capacity of Mendums Pond to assimilate phosphorus. Apparently, Mendums Pond acts as a phosphorus sink, accumulaing phosphorus in the sediments for each of the study year-months except October.

The study year sediment phosphorus uptake was 287 Kg. The minimum monthly uptake occurred in June while maximum phosphorus uptake occurred in August. October was the only month that there was a net sediment release to the water column.

C. Seasonal Phosphorus Contributions To Mendums Pond (1987-1988)

The monthly and total phosphorus budget was derived from the aforementioned components and measured phosphorus concentrations. The following discusses monthly or seasonal phosphorus loading by each of the components to Mendums Pond.

Budget components and phosphorus data were derived for the months November, 1987 through October, 1988. Monthly phosphorus loading to Mendums Pond by two major inflowing tributaries is presented in Figure VIII-5. In a normal hydrologic year, much of the monthly phosphorus loading occurs from late February to early April when winter snowmelt erodes subwatershed material and strips phosphorus which has accumulated since fall. However, the combination of a below normal winter snowfall and an above normal summer rainfall lead to only a moderate spring runoff and an extensive summer runoff. July and August of 1988 were noted for significant rainfall from both high intensity, short duration storms and low intensity long duration storms.

Storm events can be a significant factor in calculating a phosphorus budget. However, they are one of the most difficult parts of the budget to undertake. Accumulating storm event data can be costly; automatic equipment to sample and record flows must be purchased and operated. Nonetheless, the expense is justified if an accurate phospohrus budget is to be developed. Dennis (1986) estimated that the four largest runoff events accounted for 65 percent of the total phosphorus export to a Maine lake, and a single storm event contributed almost 50 percent of the phosphorus load to that same lake.

Mendums Pond

Net Sediment Phosphorus Flux

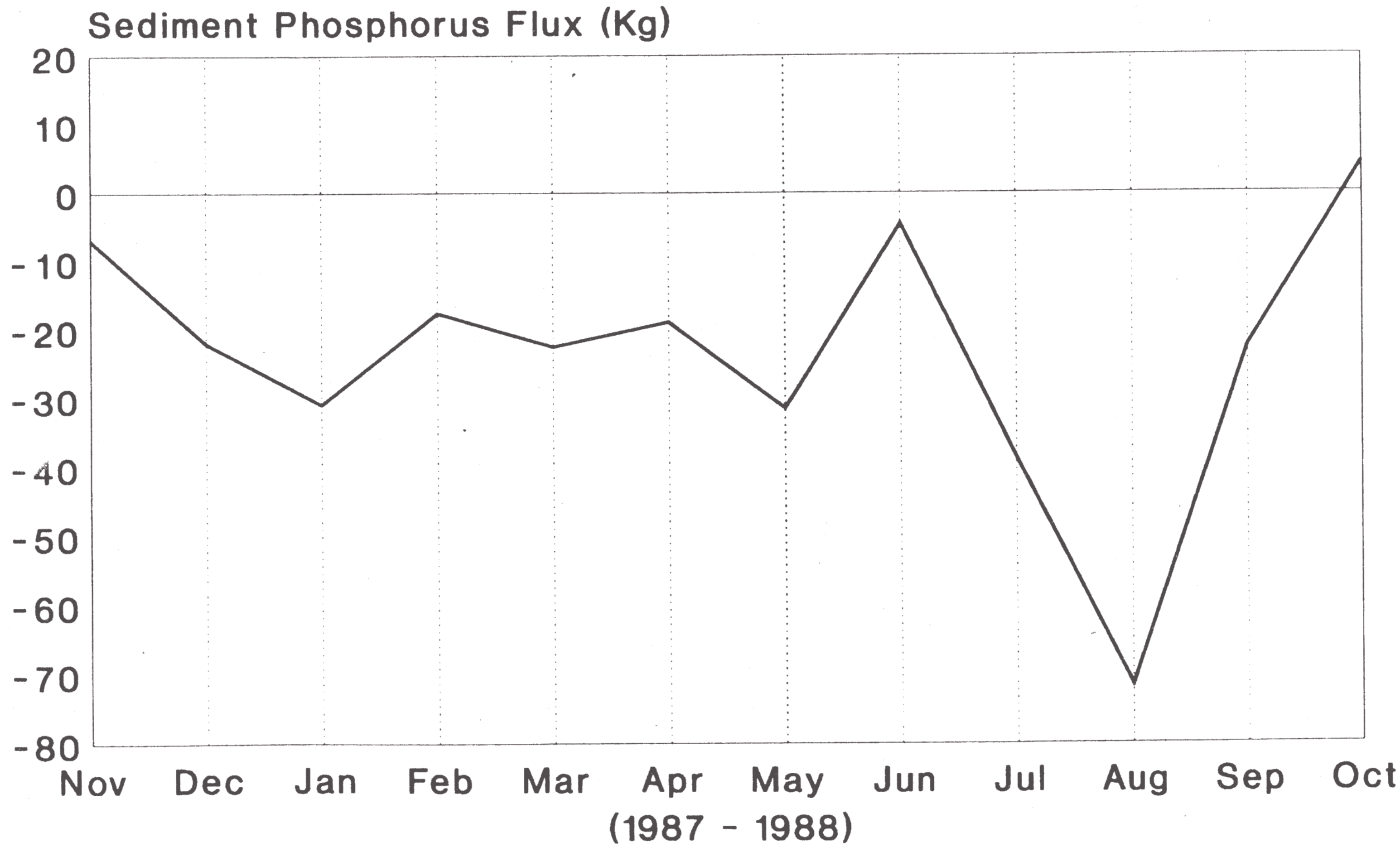


Figure VIII-4 Capacity To Assimilate Phosphorus

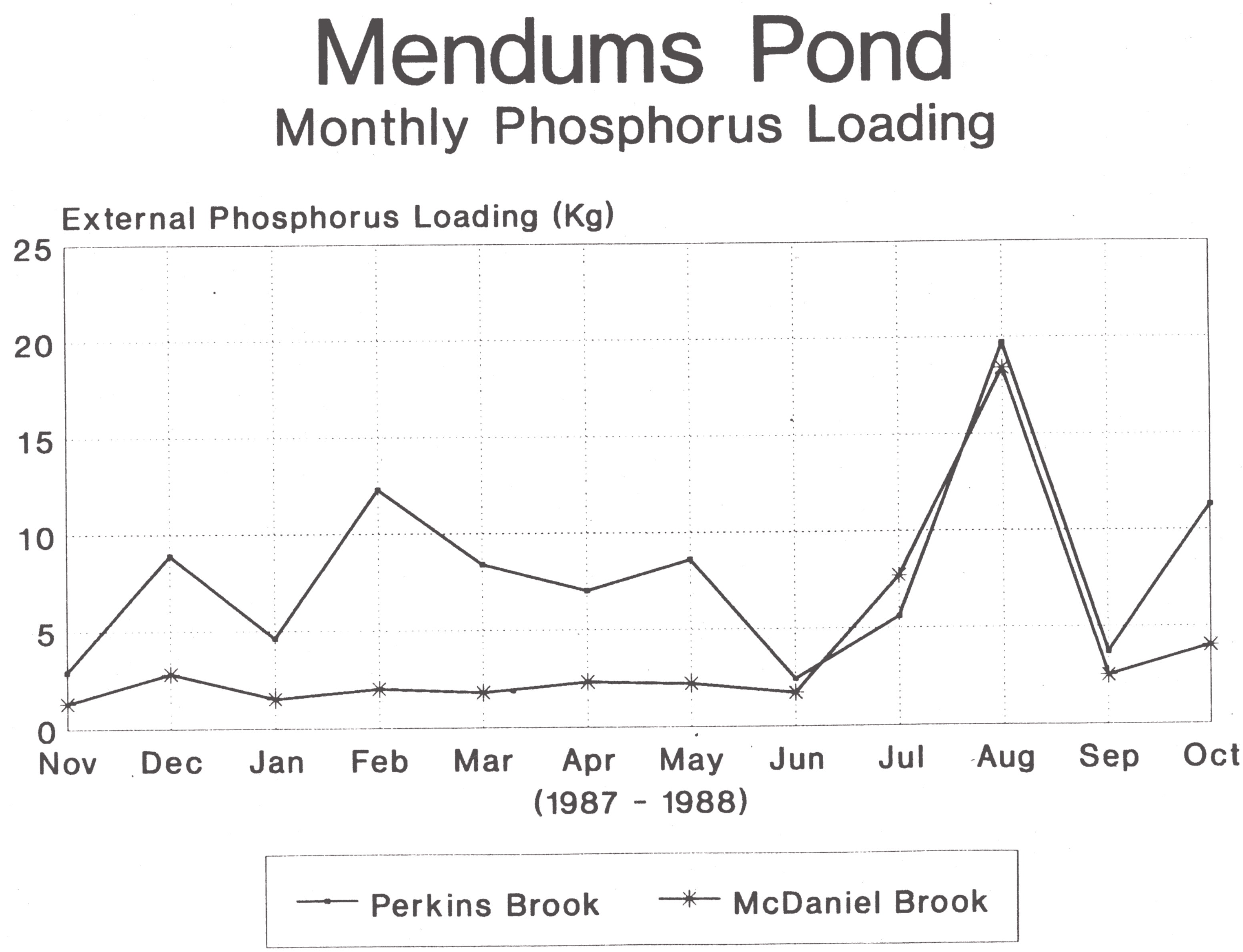


Figure VIII-5 Phosphorus Load From The Two Major Tributaries

Many studies have shown that much of the phosphorus load can occur during the first centimeter of rainfall. A study conducted in a Maine watershed estimated that 69 percent of the phosphorus export occurred during the first centimeter of runoff while 90 percent and 97 percent occurred during the first two centimeters and three centimeters respectively.

Monthly external phosphorus loading trends, exclusive of tributary loading, are presented in Figure VIII-6. Atmospheric contribution depends upon the amount of precipitation that occurs over a given period of time. Atmospheric contribution and runoff loading during the winter months is often low because precipitation is usually in the form of snow, and runoff is slight. As the phosphorus budget reveals, 42 percent of the atmospheric load to Mendums Pond occurred during the heavy rainfall months of July and August of 1988. Direct runoff is dependent upon precipitation and soil conditions. Generally, the spring melting of the winter snowpack in combination with semi-impermeable frozen soils lead to high direct phosphorus runoff. High intensity rain events also increase direct runoff of phosphorus as little of the fallen precipitation has the opportunity to percolate through the soils. Low intensity storm events usually produce little direct runoff phosphorus as much of the water is absorbed into the usually dry summer soils.

Seasonally, little direct runoff was calculated for the winter months for Mendums Pond. Direct phosphorus runoff increased during spring, decreased in May and June but dramatically increased in July and August when rainfall increased. Direct runoff was lower during the fall as these months were below the seasonal precipitation norm.

Groundwater loading of phosphorus to the lake also followed seasonal patterns. An increase in water table forces more water and phosphorus into the lake. In the same manner, an increase in septic system usage will increase the quantity of water in the saturated lake shoreland water table, and increase the nutrient loading to the groundwater.

Mendums Pond received much of its groundwater phosphorus during the late spring when the ground thawed and during the wet summer months.

Septic export of phosphorus remained fairly constant during the winter and spring, but increased dramatically during the summer. This summer increase in phosphorus loading coincided with the return of transient home owners and consequently the utilization of their septic systems. By mid-fall export values returned to pre-summer levels.

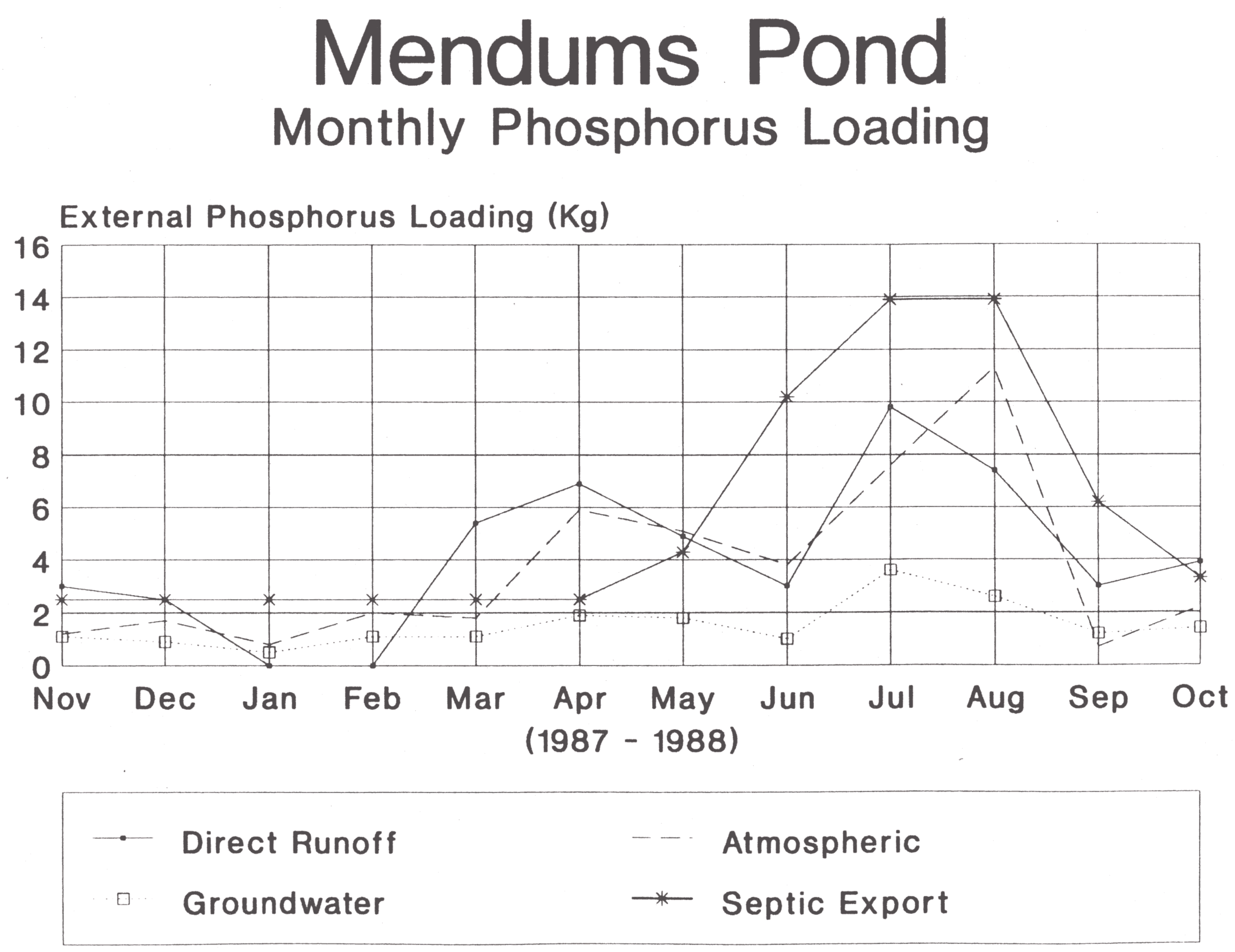


Figure VIII-6 Monthly External Phosphorus Load, Exclusive Of Tributaries

Figure VIII-7 presents total monthly external loading over the 1987-1988 study period. Maximum loading was achieved during July and August of 1988. These typically dry two months yielded 38 percent of the annual phosphorus load to Mendums Pond. The above average rainfall, higher water table, increased watershed runoff and increased septic load all contributed to the maximum phosphorus load to Mendums.

In a normalized sample year, a combination of high volumes of watershed snowmelt water and the meltwater capacity to carry phosphorus-laden particulates are the contributing factors to loadings in February and March or March and April. However, only 14 percent of the annual phosphorus load was delivered to Mendums Pond during March and April of the study period.

D. Annual Phosphorus Budget for Mendums Pond (1987-1988)

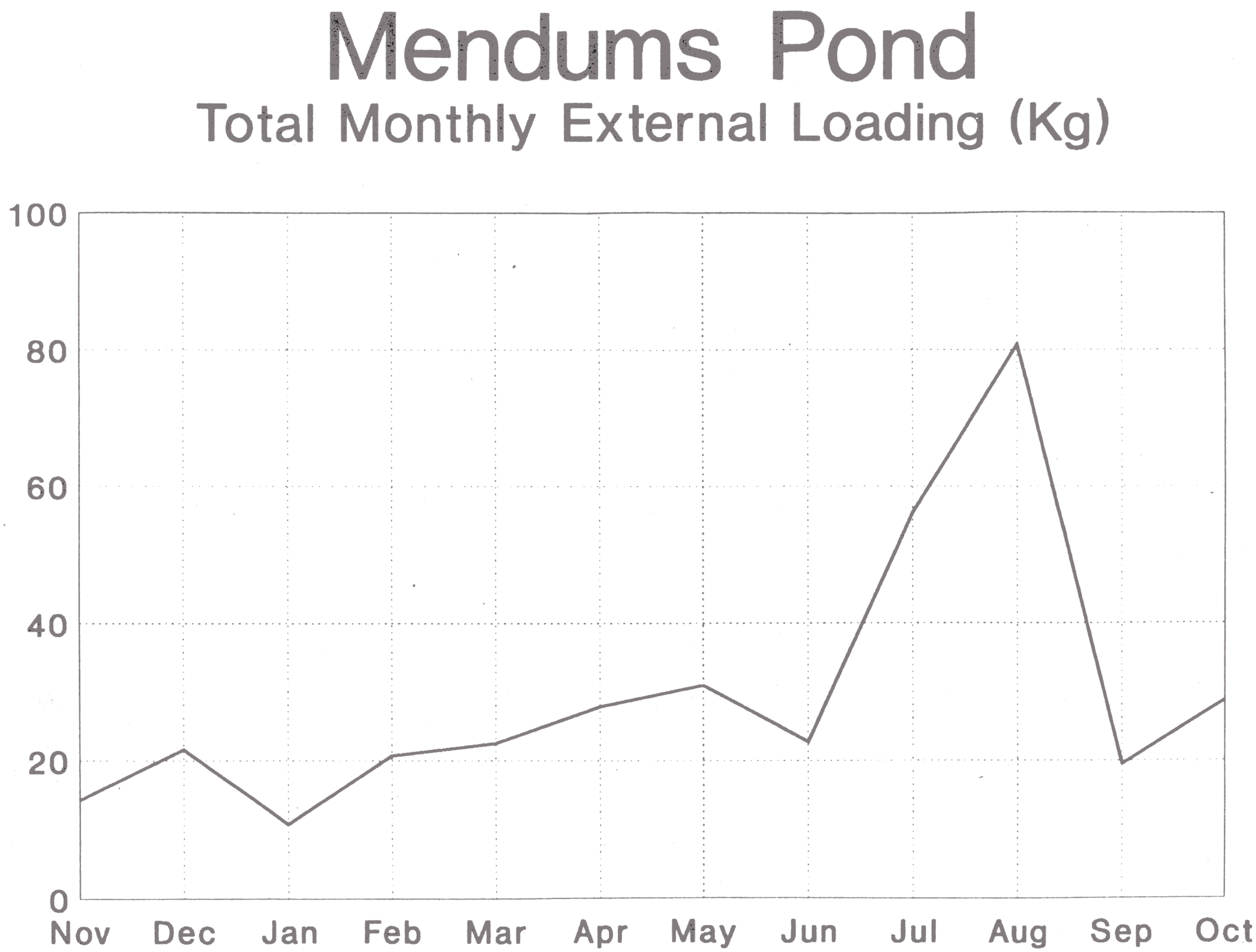
The total phosphorus budget as a whole and the percent contribution of each component to Mendums Pond is one of the most important products of this study.

A pie diagram (Figure VIII-8) shows the external phosphorus contribution to Mendums Pond as percent of the total budget, while Table VIII-8 presents the 1987-1988 gaging year phosphorus budget for Mendums Pond.

The combination of all twelve inflowing tributaries to Mendums Pond accounted for 50 percent of the phosphorus budget. The combination of three brooks, Perkins Brook (95Kg), McDaniels Brook (18Kg), and Bridge Brook (13Kg), represented 88 percent of the tributary phosphorus load to the pond. When compared to other studies, the tributary phosphorus loading was equal to that of French Pond (Connor and Martin, 1988) but was lower than tributary loading measured at Kezar Lake, which contributed 73 percent of the phosphorus flux (Connor and Smith, 1983) and Northwood Lake which accounted for 83 percent of the phosphorus budget (Estabrook and Towne, 1982).

The second greatest contributor of phosphorus to Mendums Pond was septic leachate which contributed 67 Kg of phosphorus and represented almost 19 percent of the total budget. Septic leachate loading at Mendums was similar to two recently completed diagnostic/feasibility studies: Webster Lake, Franklin at 16 percent (Connor and Dubis, 1990) and French Pond, Henniker at almost 20 percent (Connor and Martin, 1988).

Direct watershed phosphorus runoff into the pond contributed 50 Kg or 14 percent of the total phosphorus load to Mendums Pond.



VIII-7 Total Monthly External Phosphorus Loading

External Phosphorus Contribution to Mendums Pond

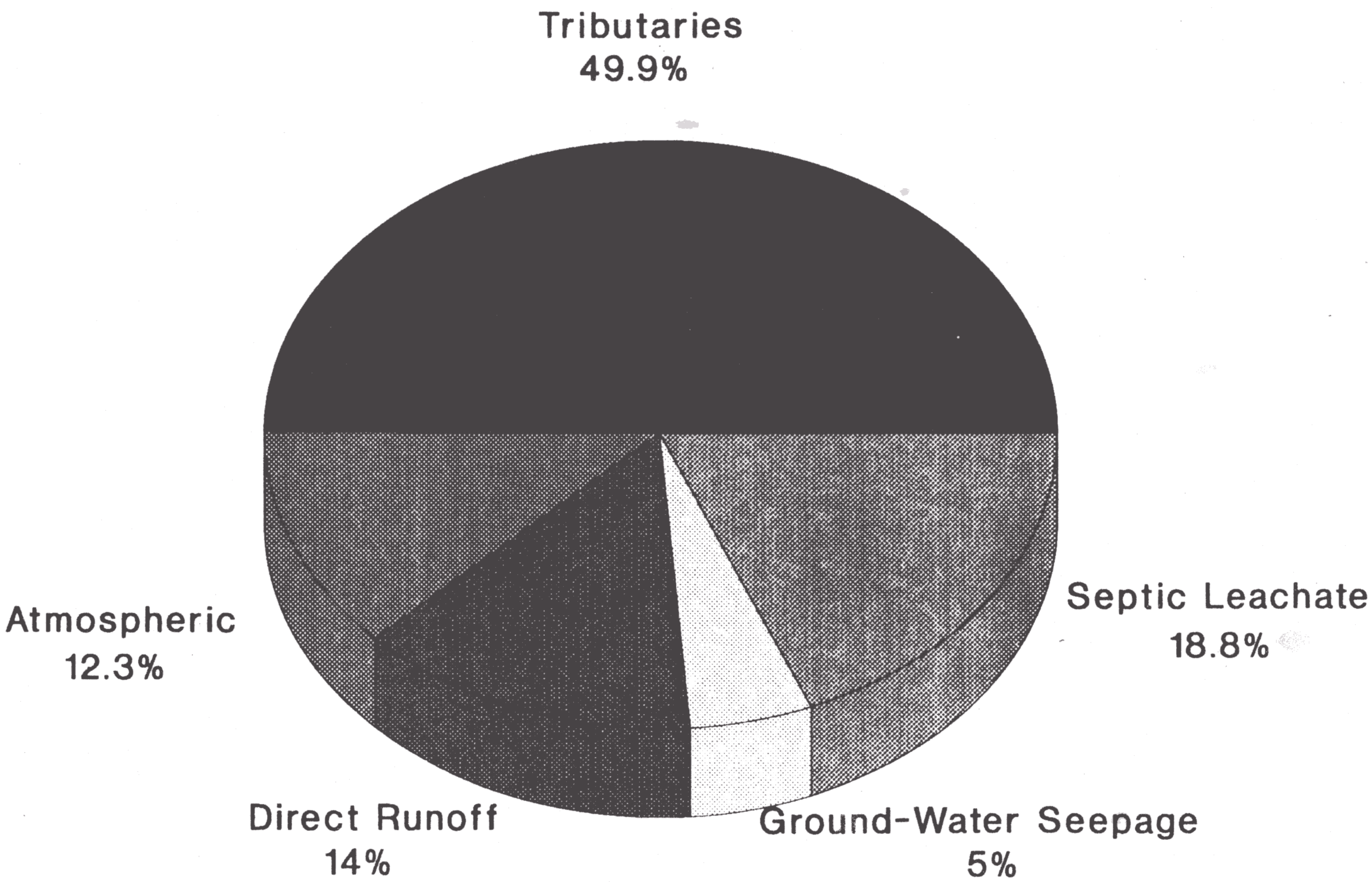


Figure VIII-8 External Phosphorus Contribution

TABLE VIII-8

Mendums Pond Gaging Year Phosphorus Budget (phosphorus loading Kg P)

Component	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88	May 88	Jun 88	Jul 88	Aug 88	Sep 88	Oct 88	Mean	Total
Qi_1 Perkins	2.9	8.9	4.6	12.3	8.4	7.0	8.6	2.4	5.6	19.7	3.7	11.3	8.0	95.4
Qi_2 McDaniel	1.3	2.8	1.5	2.0	1.8	2.3	2.2	1.7	7.7	18.4	2.5	4.0	4.0	48.4
Qi_3 Wood Rd.	0.1	0.8	0.2	0.2	0.2	0.2	0.5	0.1	0.6	1.5	0.2	0.1	0.4	4.7
Qi_4 Howe	0.9	0.3	0.1	0.2	0.2	0.1	0.1	0.1	0.3	0.4	0.5	0.1	0.3	3.4
Qi_5 Powerline	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	1.8
Qi_6 Golden Brook	0.2	0.2	0.1	0.1	0.6	0.1	0.1	0	0.5	0.5	0	0.3	0.2	2.9
Qi_7 Bridge Brook	0.2	0.7	0.1	0.2	0.2	0.4	2.7	0.2	4.7	1.6	1.4	1.0	1.1	13.4
Qi_8 Little Powerline	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<.01	<.01	<.01	0.3
Qi_9 Seasonal Powerline	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	0.2
Qi_{10} Howe 2	0.1	0.1	0.1	0.1	<0.1	<0.1	0	0.1	0.1	0	0	0.1	<0.1	0.6
Qi_{11} Little Bridge Bk.	0.6	0.1	0	0	0.1	0.2	0.3	0	1.6	2.9	0	0.9	0.6	6.6

TABLE VIII-8

Mendums Pond Gaging Year Phosphorus Budget (phosphorus Loading Kg P)

Component	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88	May 88	Jun 88	Jul 88	Aug 88	Sep 88	Oct 88	Mean	Total
Qi_{12} Storm Brook	0	0	0	0	<0.1	<0.1	0	0	0	0.3	0	0	<0.1	0.4
P Lake Atmospheric	1.2	1.7	0.8	2.0	1.8	5.9	5.1	3.8	7.6	11.3	0.7	2.2	3.7	44.1
Direct Runoff	3.0	2.5	0	0	5.4	6.9	4.9	3.0	9.8	7.4	3.0	3.9	4.2	49.8
GWI Ground-water Seepage	1.1	0.9	0.5	1.1	1.1	1.9	1.8	1.0	3.6	2.6	1.2	1.4	1.5	18.2
Septic Leachate	2.5	2.5	2.5	2.5	2.5	2.5	4.3	10.2	13.9	13.9	6.2	3.3	5.6	66.8
Sub Total	14.3	21.6	10.8	20.7	22.5	27.8	30.9	22.7	56.2	80.8	19.5	28.7	29.7	356.5
Net Sediment release (+) uptake (-)	-6.9	-21.9	-30.8	-17.5	-22.4	-18.8	-31.4	-4.5	-38.7	-71.6	-22.3	+4.3	-23.9	-282.8
Total Influx	+7.4	-0.3	-20	3.3	0.1	9.0	-0.5	18.2	17.5	9.2	-2.8	33.0	6.2	74.1
Total Outflow through outlets	9.7	8.2	6.0	3.3	<0.1	3.2	10.6	0.2	2.6	10.5	4.1	5.9	5.4	64.3

Atmospheric deposition delivered 44 Kg of wetfall and dryfall phosphorus to Mendums Pond during the 1987-1988 study year. To a lesser extent, groundwater seepage contributed 18Kg of phosphorus to Mendums which accounted for five percent of the total phosphorus budget. Seepage phosphorus contributions generally range from one to ten percent of a nutrient budget.

Oxygen deficiencies were measured in the hypolimnion of Mendums Pond for only 15 percent of the study year. Hypolimnetic anoxia is highly conducive to the release of phosphorus from the sediment and interstitial water to the immediate water column. Increases of hypolimnetic phosphorus in Mendums Pond coincides with low hypolimnetic dissolved oxygen during late August and early September. Hypolimnetic phosphorus and dissolved oxygen data reveal that there is currently little problem with internal loading.

Although the Mendums Pond phosphorus budget shows a net uptake of phosphorus, it must be emphasized that sediment release and uptake are simultaneously occurring functions in different sections of the lake, and that other chemical, physical and biological activities are also occurring. While one section of the lake may be releasing phosphorus for some of the year, other areas of the lake are uptaking phosphorus. As discussed previously in the sediment release section, only one month showed a net release of phosphorus to the water column.

The study year phosphorus budget reflects a subtotal annual phosphorus influx of 357 Kg. The estimated net sediment uptake was 287 Kg. The total influx to the pond after sediment uptake was 74 Kg, in which 64 Kg left the lake through the ponds two outlets.